MECHANICAL EFFICIENCY OF ROWING FOR ELITE FEMALE ROWERS IN JAPAN

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ABSTRACT

The purpose of this study was to determine the mechanical efficiensy of rowingergometer exercise and to evaluate it from rowing motion analysis. Twenty eight junior female rowers (4-skilled championship crew of Japan National Regatta in 1984 and 24-unskilled) served as subjects. The average age of subjects was 16.6±1.1 years (Mean±SD) and the mean values of $\dot{V}O_2$ max were 2.4±0.3 l/min and 42.1±3.7 ml/kg·min. Each subject was tested three-minutes maximal sweep rowing at a competitive performance level on a Gamut Rowing Ergometer. Work output was calculated by the flywheel revolutions (rpm) on the ergometer. Energy cost was computed from total net oxygen consumption. Expired gas was collected by the open-circuit method and analyzed using the Scholander technique. The rowing motion was filmed by 16mm cinecamera with 48fps during rowing ergometer exercise. the films were analyzed frame by fram for drive phase of strokes utilizing NAC motion analyzer with digitizer. Mechanical efficiency (ME) of rowing ergometer exercise was 11.4±0.4 % for the skilled and 10.6±0.7 % for the unskilled. ME of the skilled was significantly higher than that of the unskilled ($p<0.05$). Based on the ratio of actual to possible sum of knee and trunk angular velocity when the oar was perpendicular to the shell, motion analyzed efficiency (MAE) was calculated with the formula of Nelson et al. (1983). MAE of rowing ergometer exercise was 89.4±3.8 % for the skilled and 76.6±10.9 % for the unskilled. MAE of the skilled was also significantly higher than that of the unskilled ($p<0.05$). These results suggested that ME of simulated rowing might be improved by the routine training and that MAE would be one of factors which influence on ME. Therefore, it is concluded that ME could be useful to assist the coach for junior female rowers in establishing both training program and rowing technique of each individual.

INTRODUCTION

Competitive rowing performed over a distance of 2000m for men and 1000m for women with high-intensity exercise. Previous experience with exercise testing of rowers has shown that a high aerobic capacity in an importat criterionfor international rowing success. However, rowing performance is determined not only by aerobic capacity, muscular power and training etc, and also influenced by skill to a great extent. As index of rowing skill, mechanical efficiency in rowing movement has been noted and measured in a basin or a rowing ergometer. In the previous studies of mechanical efficiency, the measurment were almost performed for elite male rowers but a few studies for female rowers. Moreover, few study has been discussed mechanical efficiency from a point of view in motion analysis for female rowers.

Therefore, the purpose of this study was to determine the mechanical efficiency of rowing ergometer exercise for junior female rowers and evaluate it from rowing motion analysis.

METHODS

Twenty eight junior female rowers (4-skilled championship crew of Japan National Regatta in 1984 and 24-unskilled)were served as subjects. Japanese original racing boats, namely Knukle four has mainly being used for female rowers. Therefore, they were rowers of Knukle four. Physical characteristics of subjects were shown Table 1. Each subjects was tested three-minute maximal sweep rowing at a competitive level on a Gamut Rowing Ergometer. Work was calculated by following equation of Tsunoda et al.(1978).

$$W=2\cdot\pi\cdot r\cdot g\cdot N\cdot M$$

where W=work (joules); π=3.14, ratio of circle; r=0.184(m) radius of fly-wheel on ergometer; g=9.8(N),accleration of gravity; N=flywheel revolutions (rpm) after 3-min maximal rowing; M=1.25(kg), work lord. Energy cost was calculated from total net oxygen consumption. Expired gas was collected by open-circuit method during following min; exercise of 0 to 1, 1 to 2, 2 to 3, and recovery of 0 to 1, 1 to 2, 2 to 4, 4 to 8, 8 to 15, 15 to 30, 30 to 40 min. The last duration showed rest oxygen consumption as the baseline. Gas volumes were measured using a dry gas meter and samples analyzed using the Scholander technique. Heart rate(HR) was recorded during the last 30 seconds of each gas collected duration by direct electrocardiography. Kilocaloric equivalents were calculated assuming equivalent of 5.05 Kcal/l O_2 (based on an RQ of 1.00). Mechanical efficiency (ME) was determined with the formula (net efficiency=Work / Energy cost above at rest)

The rowing motion was filmed by 16mmmm cinecamera with 48fps during rowing ergometer exercise. THe camera was positioned at right angles to the plain of motion at a distance of 15m. A bord marked with a length of 1m was filmed in the location of the rower's body to determine the conversion factor from film length to actual linear length. At least three complete strokes were filmed to allow the camera to reach the disired speed during the last 30 seconds of each minute in exercise. The films were analyzed frame by frame for drive phase of strokes utilizing NAC motion analyzer with digitizer. The joint angles at the knee, hip and the inclination of the trunk were defined according to the convention shown in Figure 1. Based on the ratio of actual to possible sum of knee and trunk angular velocity when the oar was perpendicular to the shell, motion analyzed efficiency (MAE) was calculated with the following equation of Nelson et al.(1983)

$$MAE = \frac{\text{actual sum of trunk and knee angular velocity when the oar was perpendicular to the shell.}}{\text{possible sum of trunk and knee angular velocity if maximum angular velocity of trunk and knee occurred when the oar was perpendicular to the shell.}}$$

Table 1.
Physical characteristics for the skilled and unskilled rowers.

	Age (yrs)	Height (cm)	Weight (kg)	$\dot{V}O_2$Max (l/min)	$\dot{V}O_2$Max (ml/kg·min)
Skilled(n=4)					
$\bar{X}$	18.5	162.8	61.1	2.50	41.45
SD	0.9	2.5	1.4	0.26	2.39
Unskilled(n=24)					
$\bar{X}$	16.3	162.5	57.5	2.43	42.10
SD	0.9	4.9	6.2	0.31	3.71

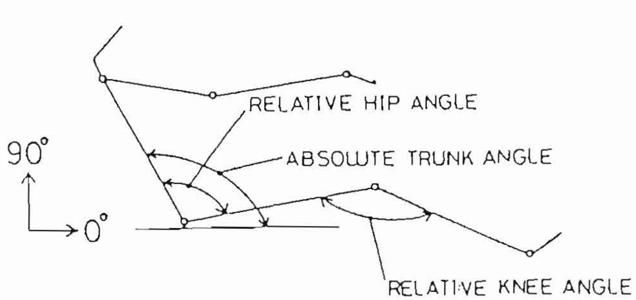

Figure 1 Schematic of rower. (cited from the deta of Nelson et al., 1983.)

RESULTS AND DISCUSSION

Changes of work of every 30 secc-ds during 3-min rowing ergometer exercise is shown Figure 2. Work of the skilled was higher than that of the unskilled. But changes of work indicated similar tendecies, that is, the first rapid increases were caused by the start spurt and the final increases were caused by the last spurt. Sum of work was 23070.2±2571.9(j) for the skilled and 20456.5±2963.3(j) for the unskilled. Although work of the skilled was higher than that of the unskilled, there was no statistical differrence.

Changes of HR and $\dot{V}O_2$ during exercise and recovery on a rowing ergometer for the skilled and the unskilled are shown in figure 3. HR increased to 174±10 bpm for the skilled and 168±11 bpm for the unskilled by the first minute, and then increasd rapidly to 185±5 bpm for the skilled and 18±8 bpm for the unskilled by the third minute. After rapid increase during the first minute of the rowing ergometer exercise, HR and $\dot{V}O_2$ tended to level off at the near maximal aerobic capacity for both the skilled and the unskilled And then, gradually they decreasd to rest. Max HR in rowing exercise was approximately consistent with the previous reports. On the other hand, $\dot{V}O_2$ of each minute in rowing exercise was remarkably lower than the previous reports. Especially the values of peak $\dot{V}O_2$ in this study were about half as much as that of peak $\dot{V}O_2$ for elite senior female rowers in USA. However, changes of HR and $\dot{V}O_2$ in exercise showed similar tendencies to the prior studies. Work intensity of each minute in 3-maximal rowing was 65.2±2.0 % (the first min), 95.5±4.2 % (the second min), and 94.0 7.5 % (the third min) for the skilled respectivily, likewise 59.4±10.1 %, 92.7±8.6 %, and 95.4±6.6 % for the unskilled, respectivily. Work intensity at the only first min of the skilled was significantly higher than that of the unskilled ($p<0.05$). It appears that the skilled had more excellent cardiovascular response than the unskilled judging from work intensity of the first min. Total net energy cost was9.6±1.22 l/min for the skilled and 9.2±1.50 l/min for the unskilled. Although net energy cost of the skilled was higher than that of the unskilled, there was no statistical differrence.

Figure 4 shows mechanical efficiency (ME) and motion analyzed effiency (MAE) of ergometric rowing for the skilled and unskilled. ME of the rowing ergometer exercise was 11.4±0.4 % for the skilled and 10.6±0.7 % for the unskilled, in the rage of 9.0 % to 12.0 % in all. Concerning the previous investigation, Henderson et al.(1925) found ME of the order of 20 %÷25 % on a rowing ergometer. Di Prampero et al.(1971) reported 10 %-20 % in the simulated rowing in a basin and 18 %-23 % in actual rowing estimating from HR. Moreover, Tsunoda et al.(1977) (1978) (1979) reported 10 %-18 % in rowing ergometer exercise. Hagerman et al.(1978) (1979) also determined ME of simulated rowing and reported an average value of 14 % and the range of 16.0 % to 17.5 %. In this way, it is considered that ME of simulated and actual rowing in the previous reports was the range of about 10 % to 25 %. Although ME in this study was within the range of other prior reports, this result showed the lowest value with the range of ME among the others.

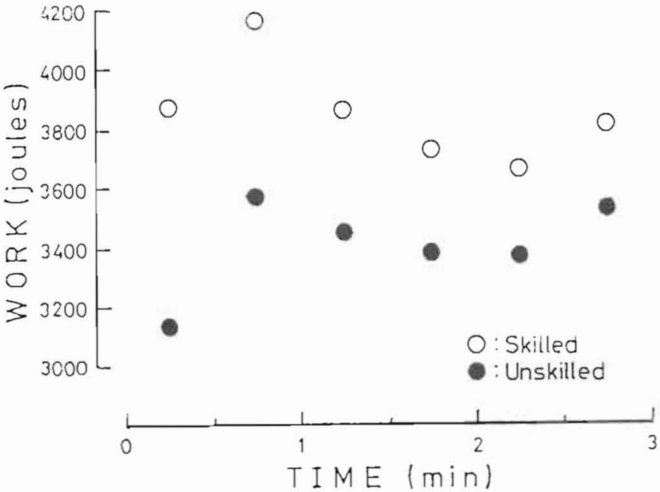

Figure 2. Work at 30 second intervals for a period of three minutes on the rowing ergometer for the skilled and unskilled.

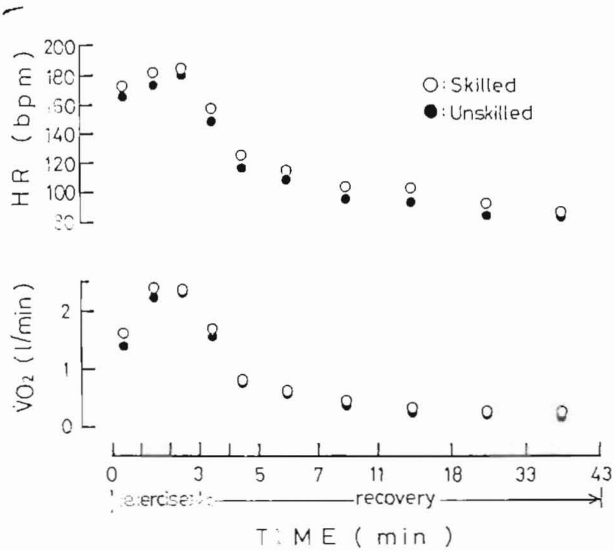

Figure 3. HR and $\dot{V}O_2$ during exercise and recovery on a rowing ergometer for the skilled and the unskilled.

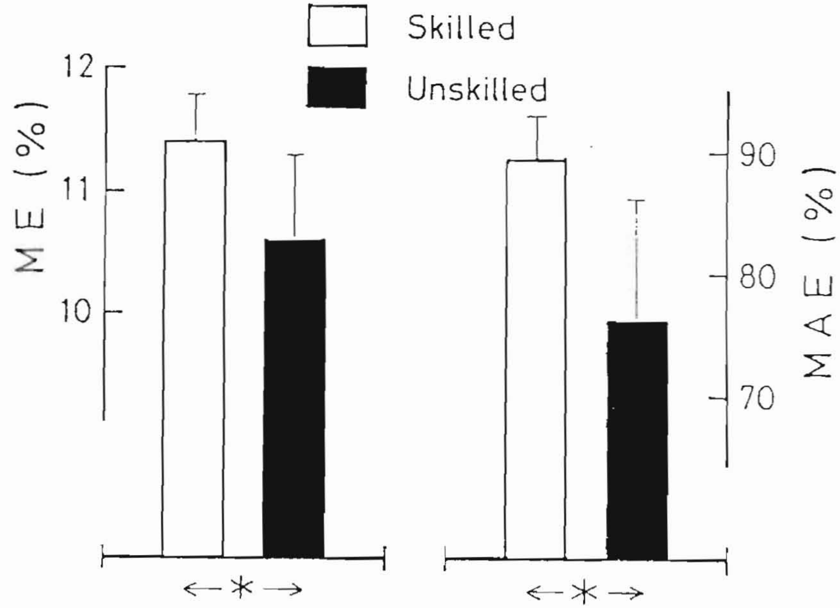

Figure 4. ME and MAE of 3-min rowing ergometer exercise for the skilled and the unskilled($* p<0.05$)

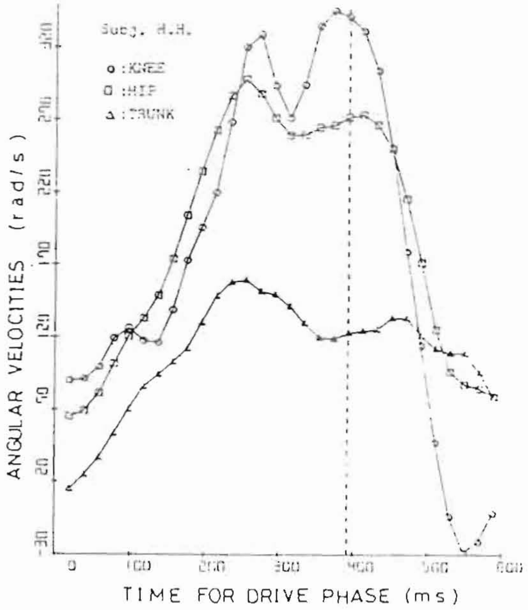

Figure 5. Typical angular velocity of trunk, knee and hip as a function of time for the drive phased of the skilled. The vertical dotted line indicates when oar was perpendicular to the shell.

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